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Patentanmeldung Nr. **Patent application No.** **Demande de brevet n°**

99850150.6

Der Präsident des Europäischen Patentamts;
Im Auftrag

For the President of the European Patent Office

Le Président de l'Office européen des brevets
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Sheet 2 of the certificate
Page 2 de l'attestation

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Bezeichnung der Erfindung:
Title of the invention:
Titre de l'invention:
Symbol synchronisation in a DMT system with crosstalk interference

In Anspruch genommene Prioriät(en) / Priority(ies) claimed / Priorité(s) revendiquée(s)

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See for original title page 1 of the description.

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Title.

Method for estimating and synchronizing to frame boundarie of mis-aligned cross- talk signals in a DMT system.

Technical area.

A telecommunications transmission system using a DTM system as multicarrier system and having at least two VDSL systems, each comprising a pair of modems, said at least two VDSL systems belonging to a single binder group common to both VDSL systems, a method in said DMT system for keeping DMT frames aligned to the same frame timing.

State of the art.

DMT is a multi-carrier technique standardised and well known for a man skilled in the art used for high bit-rate data transmission on twisted-pair lines, such as subscriber loops for telephony.

In US 5,812,523 describes a method of demultiplexing OFDM signals and a receiver for such signals. More particularly the method is concerned with synchronization in an OFDM receiver. A signal is read into a synchronization unit, in the time domain, i.e., before fourier transforming the signal by means of an FFT processor. In the synchronization unit, a frame clock is derived for triggering the start of the FFT process and for controlling the rate at which data is

supplied to the FFT processor. For OFDM reception, it is vital that the FFT process commences at the right point in time. Once the frame clock has been recovered, a frequency error can be estimated by the synchronization unit. The frequency error is used to control; an oscillator which generates a complex rotating vector which is, in turn, multiplied with the signal to compensate for frequency errors. The method can be used both with OFDM systems in which symbols are separated by guard spaces, and with OFDM systems in which symbols are pulse shaped. Our invention have put in to practice a new method which is partly based on this earlier known method.

Technical problem.

One problem that is always present is the signal cross-talk between pairs located in the same cable bundle. The cross-talk is usually described as two components, NEXT and FEXT. NEXT (Near End X-Talk) is the interference from other transmitters in the same end as the receiver. FEXT (Far End X-Talk) is the interference from other transmitters in the opposite end of the line.

DMT is a digital transmission technology relying on the orthogonality between carriers. The up-stream and down-stream transmission is done on separate sets of carriers. Thus, NEXT is associated with transmission in the opposite direction and FEXT with transmission in the same direction as the received

data. NEXT is usually the strongest interference signal, since it is generated close to a receiver that is receiving a weak signal.

The orthogonality is the best means to reduce the influence of NEXT. As long as the DMT frames are aligned to the same frame timing, the orthogonality holds and adjacent carriers can be used for different transmission directions without any capacity loss due to NEXT. This synchronisation has been posed as a problem for operators to implement, especially in an "unbundled" environment, where different operators share the same cable bundles.

Technical solution.
In accordance with the invention the solution is what is stated in the claims.

Advantages.
The new technique in this invention is a step towards the synchronized DMT, again allowing the use of adjacent carriers without any NEXT influence and the full capacity of the synchronized DMT. It is an adaptive timing technique that is easy to implement and does not need any extra communication between modems or between operators' installations.

The foregoing and other features of the present invention will be better understood from the following description with reference to the accompanying drawings, in which:

Figure 1 illustrates, in schematic form, two VDSL systems operating in the same cable with corresponding NEXT and FEXT cross-talk.

Figure 2 illustrates, in schematic form, an DMT time-domain frame format.

Figure 3 illustrates, in schematic form, an Correlator block diagram.

Figure 4 illustrates, in schematic form, an DMT frame correlation without cross-talk.

Figure 5 illustrates, in schematic form, an Cross correlation of DMT signal with DMT cross-talker at a 3 dB lower power.

In order to facilitate an understanding of the present invention a glossary of terms used in this patent specification is provided below:

VDSL	--	Very high rate Digital Subscriber Line
NEXT	--	Near End crosstalk
FEXT	--	Far End crosstalk
DMT	--	Discrete Multitone, a multicarrier system using Discrete Fourier Transforms to create and demodulate individual carriers.

Turning first to fig 1 there is illustrated a principal drawing of a situation where two VDSL systems operating in the same cable with corresponding NEXT and FEXT cross-talk. Fibre cables (not shown) feeding neighbourhood Optical Network Units (ONUs) and last leg premises connections by existing or new copper. VDSL transmits high-speed data over short reaches of twisted-pair copper telephone lines, with a range of speeds depending upon actual line length. VDSL is also a type of modem technology, enabling high-speed delivery of data, audio, and video in a digital form over the existing telephone infrastructure (copper twisted-pair phone lines called the local loop) which connects the customer premises and the carrier's central office. The basic idea behind all VDSL technology is that a special modem is attached to each end of the copper phone line, i.e. one modem at the customer premises and another one at the central office. The phone line is then exploited with the help of modulating techniques. In our invention we use Discrete Multi-Tone (DTM) as the multi-carrier modulating technology.

However is there always signal cross-talk between pairs located in the same cable bundle.

There are bascially two different forms of crosstalk in neighbouring copper pairs in the same cable: near-end crosstalk (NEXT) and far-end crosstalk (FEXT). NEXT is usually the strongest interference signal and occurs at the central office (base station)/optical network side when the weak upstream signal, is disturbed by strong downstream signals. FEXT is crosstalk from one transmitted signal to

another in the same direction and appears at the opposite end of the line, which is the premise side.

DMT is our transmission technology, which is well known for a man skilled in the art. Turning now to fig 2 there is shown the frame format of the time-domain DMT signal. The symbol itself is extended by a cyclic extension (prefix and suffix). Shaping of the outer parts of the extension is used to reduce the out-of-band interference caused by the transmitter.

The extension is created as copies of parts of the DMT symbol, as shown in Figure 2. Therefore, there is a strong correlation between parts of the time-domain signal built into the frame. The correlation of the time-domain signal by a delayed copy will then show peaks when a certain part of the frame passes the receiver. Due to the small piece of the frame length that is used for the correlation, only relatively strong signals will be clearly distinguishable. However, these are the only cross-talk signals that will cause any serious problems for the receiver. Averaging by using several frames in the correlation estimation will improve the quality of the estimate.

The invention uses the inherent property of DMT signals and that part of the signal is correlated in terms of cyclic extensions.

Via auto-correlation on the received time-domain DMT signal the time mis-alignment of cross-talkers can be estimated using the correlator shown in figure 3.

In fig 3 the received sampled DMT signal, x(k), is the sum of the signal that is transmitted from the opposite end of the line and cross-talk signals that originate from other DMT signals transmitted on neighbouring pairs in the same cable.

The received signal x(k) is divided into two branches. One of the branches delays the signal by 2N samples corresponding to the length of one DMT symbol. A new signal, y(k), is then created as the product of the two signals x(k) and x(k-2*N). The signal y(k) is divided into two branches whereas one branch delays the signal CE samples, corresponding to the length of the total cyclic extension of the DMT frame. A new signal, w(k), is created as the difference y(k) - y(k-CE). The signal, w(k), is finally fed into an accumulator unit to create the correlation signal c(k).

The implementation of the correlation algorithm will be substantially simplified by using only the sign bit of the input signal X(k).

If there are no cross-talkers present, the correlation sequence c(k) will have the principal shape as depicted in figure 3.

If, however, there are DMT cross-talk signals added to the signal, they will contribute to the auto-correlation with the same kind of correlation peaks located according to the frame timing. If the individual signals are uncorrelated, the correlation of a sum of signals equals the sum of the correlations of the individual signals. If the DMT receiver

has knowledge of its own frame boundaries, it can easily determine which correlation peaks correspond to the desired signal and the cross-talk signals, respectively. An example is shown by Figure. 5.

The time shift of the correlation peaks of the cross-talkers is a measure of the time mis-alignment relative to the desired signal. The amplitude of each cross-talk peak is a relative measure of the power of the cross-talker.

At start-up the receiver makes a correlation on the signal including the cross-talkers. Assuming that all cross-talkers are aligned to common frame timing, they will all have their correlation peaks located in a small range of time. The starting-up modem, therefore, should use the correlation information to align its own frame timing to the cross-talkers. If every starting-up modem uses this method, all modems that cause interference in each other's receivers will become aligned to the same frame timing.
The method estimating the time mis-alignment and power of cross-talk DMT signals added to a received DMT signal when the estimate is used by the modem to synchronise its own frame timing to a main cross-talkers frame timing.

Auto-correlation is used on the received signal and a delayed copy of the received signal. Correlation maxima detects that determine the frame boundaries of different DMT components of the received signal.

It is important to mention that the method uses the inherent property of DMT signals and that part of the signal is

correlated, in the time domain, in terms of cyclic extensions.
The method further comprising the step that the time mis-alignment, which illustrates in figure 5, of the cross-talk signals estimates as the distance between the correlation maximum corresponding to the desired signal (known location) and other correlation maxima.

As can bee seen in fig 5 amplitude of a correlation maximum is a relative measure of the power of the corresponding cross-talker.

The method further comprising the step that when the time offset of the cross-talk is estimated at the VTU-O, this information will be used to adjust its clock and frame boundaries to align with the cross-talker and hence orthogonality is achieved and the distortion is minimized.

The method further comprising the step that if the auto-correlation peak amplitude of the cross-talk signal is low the VTU-O can choose to not align clock and frame boundaries since the cross-talker then do not significantly contribute to the distortion and hence a threshold level will be used.

CLAIMS

1. In a telecommunications transmission system using a DTM system as multicarrier system and having at least two VDSL systems, each comprising a pair of modems, said at least two VDSL systems belonging to a single binder group common to both VDSL systems, a method in said DMT system for keeping DMT frames aligned to the same frame timing **characterised by** the steps of

- estimating the time mis-alignment and power of cross-talk DMT signals added to a received DMT signal when the estimate is used by the modem to synchronise its own frame timing to a main cross-talkers frame timing and
- that auto-correlation is used on the received signal and a delayed copy of the received signal and
- that correlation maxima detects that determine the frame boundaries of different DMT components of the received signal.

2. A method, as claimed in claim 1 **characterised in** that, the method uses the inherent property of DMT signals and that part of the signal is correlated, in the time domain, in terms of cyclic extensions.

3. A method, as claimed in claim 1 **characterised in** that, the method further comprising the step that the time mis-alignment of the cross-talk signals estimates as the distance between the correlation maximum corresponding to the desired signal (known location) and other correlation maxima.

4. A method, as claimed in claim 3 **characterised in** that, the method further comprising the step that the amplitude of a correlation maximum is a relative measure of the power of the corresponding cross-talker.

5. A method, as claimed in claim 3 **characterised in** that, the method further comprising the step that when the time offset of the cross-talk is estimated at the VTU-O, this information will be used to adjust its clock and frame boundaries to align with the cross-talker and hence orthogonality is achieved and the distortion is minimized.

6 A method, as claimed in claim 3 **characterised in** that, the method further comprising the step that if the auto-correlation peak amplitude of the cross-talk signal is low the VTU-O can choose to not align clock and frame boundaries since the cross-talker then do not significantly contribute to the distortion and hence a threshold level will be used.

7. A method, as claimed as claimed in any previous claim **characterised in** that the presented method to estimate frame boundaries of cross-talkers can be used for several other

applications, e.g., NEXT cancellation algorithms and multi-user detection algorithms.

8. A method, as claimed as claimed in any previous claim **characterised in** that the presented method to estimate frame boundaries of cross-talkers every starting-up modem in a system uses this method result in that all modems that cause interference in each other's receivers will become aligned to the same frame timing.

Abstract

In a telecommunications transmission system using a DTM system as multicarrier system and having at least two VDSL systems, each comprising a pair of modems, said at least two VDSL systems belonging to a single binder group common to both VDSL systems, a method in said DMT system for keeping DMT frames aligned to the same frame timing.

The steps is

- estimating the time mis-alignment and power of cross-talk DMT signals added to a received DMT signal when the estimate is used by the modem to synchronise its own frame timing to a main cross-talkers frame timing and
- that auto-correlation is used on the received signal and a delayed copy of the received signal and
- that correlation maxima detects that determine the frame boundaries of different DMT components of the received signal.

Fig 1

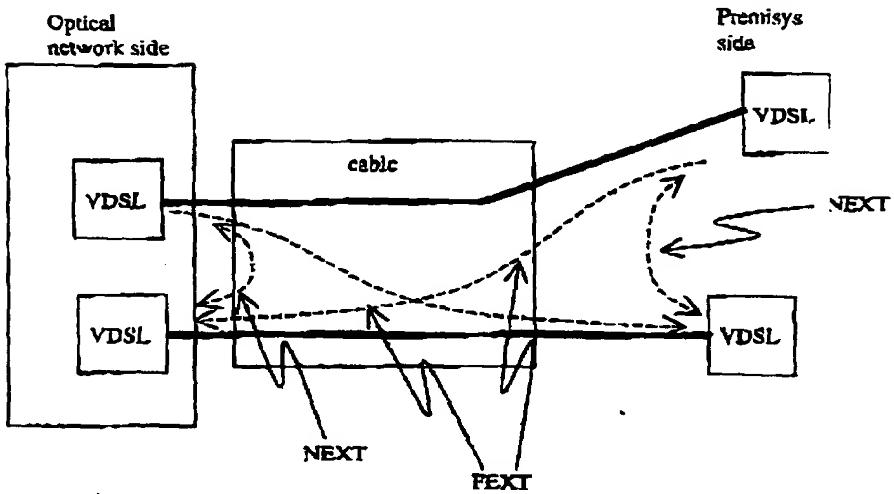

Optical
network side
Premisys
side
cable
VDSL
VDSL
VDSL
VDSL
NEXT
NEXT
FEXT

Fig 2

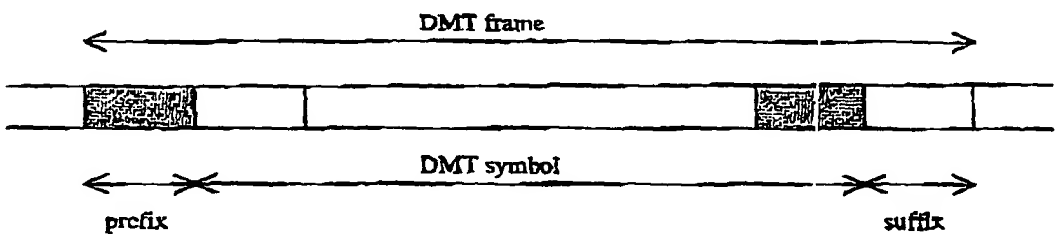

DMT frame
DMT symbol
prefix
suffix

Fig 3

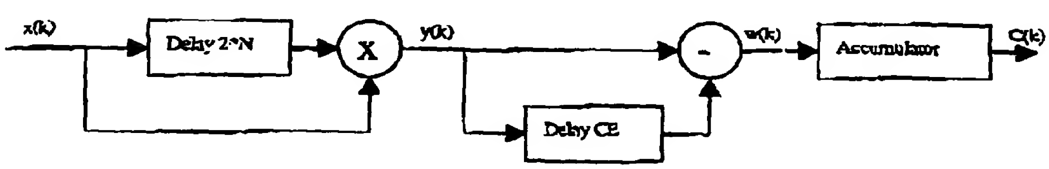

x(k)
Delay 2*N
X
y(k)
-
Delay CE
Accumulator
C(k)

Fig 4

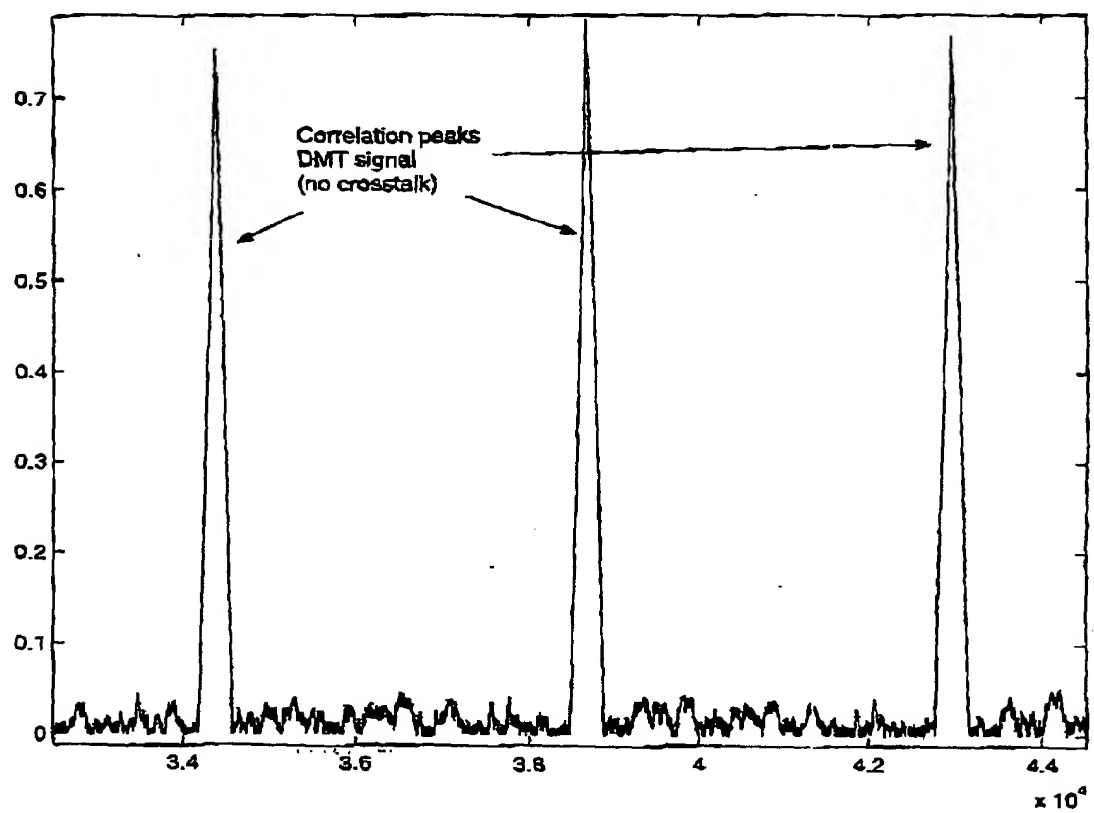
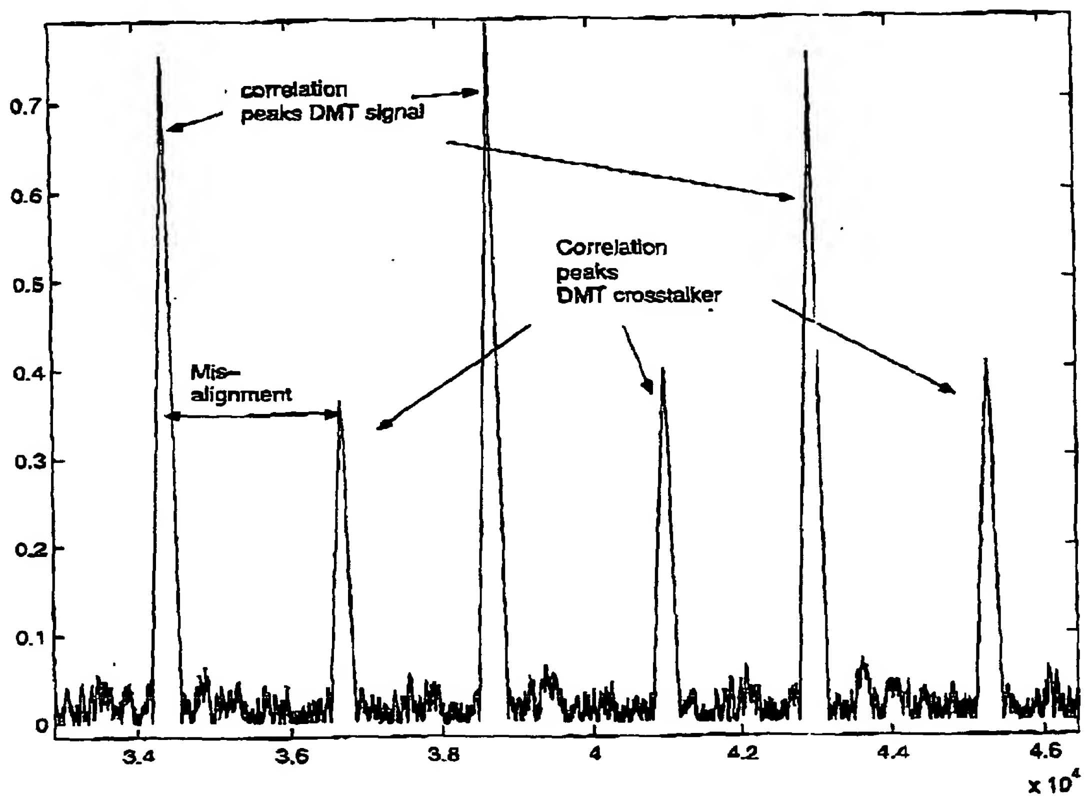

Correlation peaks
DMT signal
(no crosstalk)
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
3.4
3.6
3.8
4
4.2
4.4
x 10⁴

Fig 5


correlation
peaks DMT signal
Correlation
peaks
DMT crosstalker
Mis-
alignment
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
3.4
3.6
3.8
4
4.2
4.4
4.6
x 10^4